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The new "OLD BRIDGE" over the Danube river in Bratislava

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Abstract

The main task of the project was to span the river Danube towards Petrzalka with the multiple rail 1000/1435 (tram-train type) and to temporarily finish it behind the Bosakova street. The most important project section is the „new" Old bridge over the Danube. It has the length of 461,4m. The part of the contract was a demolition and disposal of the original bridge structure and a partial removal of the lower part of the structure. The new steel structure SO 20-201-00 with spans 32,56m + 106,68m + 137,16m + 75,60m + 75,92m + 32,56m in sections II to V has a constant theoretical height of the main beams of 10,50m.

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Keywords: Old Bridge; Danube; steel; extension; floating support

1. Introduction

The paper is a follow-up to a paper presented at last year's symposium entitled „The New Old Bridge Project, Bratislava". For the sake of completeness, the basic information on the bridge is repeated here. The „Old Bridge" is part of the construction project „The Pivotal System of City Mass Transportation, Operational Section Janíkov Yard – Šafárikovo Square in Bratislava, Part 1. Bosáková Street – Šafárikovo Square", as implemented in the capital city of the Slovak Republic, Bratislava. The project was undertaken by an association of companies: EUROVIA SK a.s., EUROVIA CS a.s., and SMP CZ a.s. The main purpose of this construction project is to interconnect the communication system of the City of Bratislava between Šafárikovo Square on the Bratislava side (river bank) of the Danube and Bosáková Street on the Petržalka side (river bank). The siting of the bridge respects the original siting of the Old Bridge within the existing corridor exiting to the Šafárikovo Square intersection. The contractor for this new „Old Bridge" is EUROVIA CS Corporation, Bridge & Structure Works (závod Mosty a konstrukce), the

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documentation used in the execution of the construction project was prepared by a consortium of Alfa 04 Corp. and SHP Co. Ltd. Corresponding author was Miroslav Matascik.

2. Dismantling the original Old Bridge

The project of dismantling the original truss assemblies constituting the road bridge dating from 1946 and the railway bridge built in 1950 posed a technical challenge of its own. The bridges were comprised of seven simply truss beams having the spans of 32.07 + 75.85 + 75.85 + 92.08 + 75.73 + 76.11 + 31.9 m. The principle of the dismantling operation consisted in interconnecting the individual simple spans so as to form a continuous structure, supported it on a line of riverboats and subsequently, dismantling this to its constituent parts in a step-wise fashion. The truss structure was dismantled using an AC-40 crane which was moving along the upper chord of the truss structure.

3. Description of the new bridge

The contractor for the specification of the construction project, Alfa 04 Corporation, has worked out several variants of the new, modern structure making use of most of the existing piers. The possibility of using some components of the original steel structures was also examined. Finally, a design of conservative shape was selected involving a straight-chord truss structure of the rhombus system believed to accommodate the nostalgic sentiments of the public.

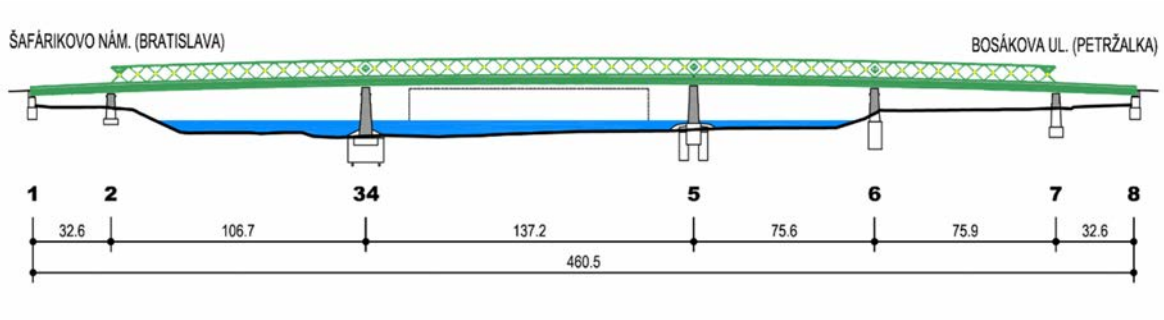


Fig. 1. Longitudinal section

The bridge provides for the passage over the river of the bidirectional, double-track streetcar and tram-train line having a track gauge of 1000 and 1435 mm, as well as bidirectional pedestrian pathways (of 2×3.0 m in width) and for cyclists (of 2×1.25 m in width). The bridge traverses Danube River where the standard gabarit for shipping is 10 by 100 m, and connects the two riverbanks. The dual-track rail line is led within a transportation band having 8.0 m in width that meets the parameters of road communication for MZ8/50, and will therefore also be well-suited for the passage of vehicles of the rescue services. A top the abutments within the riverbed (34 and 5) there are viewing terraces with benches and greenery.

The bridge is of a total length of 462 m, with spans of 32.56 + 106.68 + 137.16 + 75.6 + 75.92 + 32.56 m — cf. Fig. 1. Directionally the routing at the site of the bridge is straight, the vertical alignment (formation line) is at the circular arch having a radius of 5600 m.

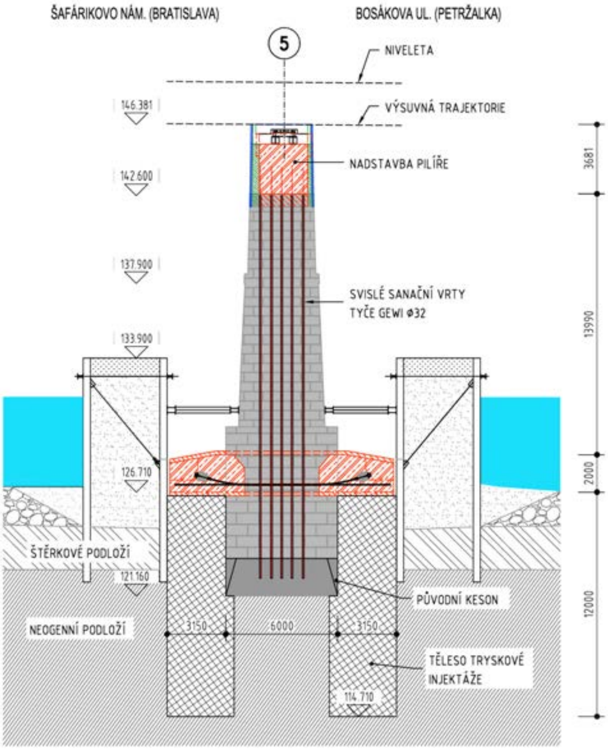
4. Foundations and substructure

Out of the original piers dating back to 1890, the preserved piers nos. 2, 5, 6, and 7 have been reconstructed and heightened. The original abutments have been widened and provided with new retaining walls and bottom sills. The piers are comprised of stone masonry with a concrete core. For the reason of extending the main bridge span from the original 92 m to 137.2 m it has been necessary to remove the piers 3 and 4 within the river course; these have been replaced with a new reinforced-concrete pier 34 with stonework masonry and lining. The foundation, substructure and shaft of abutment 5 had to be strengthened. All operations connected with the renewal of outer stonework lining of the substructure proceeded under the supervision of the Heritage Care Department.

Fig. 2. View from the left bank - piers 34 and 5

The foundations of abutments 34 and 5 within the riverbed were designed to be made of blocks of jet injection grouting, which was done from artificial islands using drilling across a layer of soil (to be later removed) or under the protection of formwork. The work on the piers proceeded under the protection of a holes lined with a dual sheet pile (pile plank) tied together with steel tie bars. The greatest problem when constructing the holes proved to be the piling of obliquely inclined front walls of the holes facing the rapidly flowing Danube waters. For these walls, auxiliary structures made of pile planks had to be piled in, with the individual parts of the inclined walls braced against them. The powerful streaming of the river came to manifest itself during the floods in August 2015 on the fully backfilled hole P34 prior to excavating the hole: there the protective rip-rap backfill came to be partially damaged and the hole began be defeated to substantial deformation; this was an emergency where a total destruction of the hole threatened. The foundations of the piers are protected against erosion by streaming water by an extra concrete protection layer and by rip-rap of stone. The extent of rip-rap necessary as well as the composition and weight of the stone blocks used was determined based on hydraulic investigations conducted by STU (Slovak Technical University) Bratislava.
The shaft of pier 5 was strengthened by remediation boreholes fitted with GEWI ϕ32 mm rods. The transmission of load from the jet injection grouting block to the original pier is ensured by a new foundation of reinforced concrete. The interaction of the new foundation with the original pier is provided for by shearing tooth systems, pasted reinforcement, and supplementary pre-stressing by cables – cf. Fig. 3. The superstructure of the pier having 3.7 m in height was built in three stages. In the first stage, a load-bearing core was made of concrete, provided with bearings to allow for sliding out the steel superstructure; subsequently, a peripheral layer of concrete was added serving as a precision substructure for stonework lining of only 70 mm thickness.

Pier 34 was built in several stages. With a view to the rapid pace of construction of the superstructure, two columns 3.15 m wide were built first to support the superstructure while sliding out. Subsequently, the widened bottom part of the pier was built where concrete was laid directly into the granite lining which comprised the formwork – see Fig. 4. The upper part of the shaft received its limestone lining only after the concrete was laid.



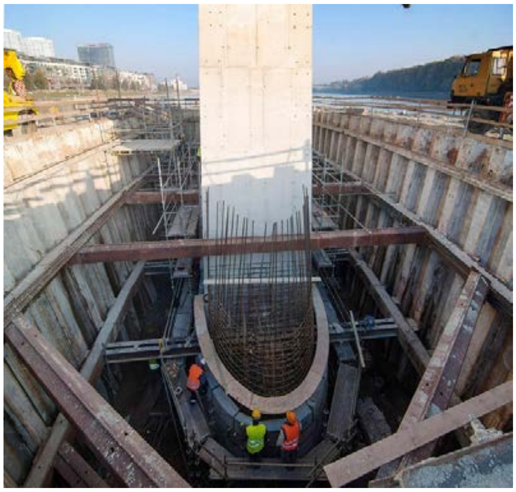


Fig. 3. Reconstruction of a pier P5

Fig. 4. Construction of a pier P34

5. Description of the superstructure

The superstructure of the Old Bridge is comprised on one single dilation unit. The steel superstructure consists of two main truss beams having a total height of 11.285 m at an axial distance of 11 m, of truss cross-beams having heights of 1.3 - 2.6 m at an axial distance of 7.56 – 8.14 m, of longitudinal beams, bridge deck plates with reinforcements, and of stiffeners. The width of the superstructure including the pedestrian walkway consoles is 22.25 m, but above the abutments 34 and 5 it is widened locally by including the viewing terraces, to a width of 33.25 m.

The bridge deck in its roadway part is made of steel plate and reinforced concrete plate of a thickness of 0.205 - 0.235 m; these are tied together by mandrels. On the topside of the plate there is a thin-walled, polyurethane based insulation suitable for supporting vehicular traffic. Within the plate there are four troughs left out, of 0.45 m width, used to hold the rail superstructure of the EDILON recessed rail system. The sidewalk plates are provided with a polyurethane base insulation suitable for supporting pedestrian traffic.

Fig. 5. Load bearing structure – truss beams and bracings

6. Manufacture of the superstructure

The steel superstructure was manufactured at the Bridge Works of Vítkovice Power Engineering Corporation, with the exception of the walkway consoles manufactured by OK Třebestovice Co. With a view to the size of the manufactured parts the structure was subdivided into 28 assemblies, for the purposes of the entire manufacturing and assembling process. Each subassembly was composed of main beam weldments, wholly welded, divided into lower and upper bands and diagonal struts, bridge deck pieces, and truss stiffeners. Owing to size and weight of the components, the manufacture of the main beams (approx. 50 tons) took place in the largest production bay equipped with two cranes of 50 tons carrying capacity. The bridge deck components together with the truss cross-beams were manufactured and handed over in the form of sub-assemblies placed on a fixture bed 45 meters long, in a reversed position. Owing to the geometrical intricacy of the structure being made, as well as to the fact that their manufacture was split between two production bays, the hand-over and acceptance procedures themselves also were rather challenging. The geometry of the assemblies was evaluated using a 3D model, in order to ensure exact fitting of the various parts during assembly on site.

7. Assembly and extension of the superstructure

The steel structure of the bridge was assembled on the right Danube riverbank, in the area between abutment 6 and abutment 8 where an assembling plant was set up. The assembling plant facility comprised a steel structure supported on reinforced concrete columns. The bridge structure was assembled of parts having ca. 15-22 m in length. The main beams were subdivided height-wise into three parts: the lower and the upper element with their attached diagonal struts and gusset plates, and the intermediate inserted diagonals. The maximum weight per segment of the main beam was 50 tons. The bridge deck was split longitudinally into three sections. The individual bridge deck segments contained two cross-beams. The sidewalk segments of 5.4 m in width but the sidewalk cross-beams were self-contained. First the bridge deck segments were welded together; the bottom components of the main beams were laterally attached to them, and to these were spot welded the intermediate diagonal pieces. Then the components of the upper element of the main beam were put in place and after they have been partially welded the upper stiffener was attached. Once the component was connected to the part of the structure already in position the next extension cycle was started to slide out the structure. As the last operation, the sidewalk consoles were attached.

The extension process was broken down into 11 cycles whereby the structure was caused to slide out by means of 4-8 pcs of pull rods (tie members of pre-stressing rods ϕWR36 mm) anchored to the cross-beams of the superstructure of the bridge. The extension device was situated on pier 6 which was stiffened for this purpose by angle strut braces. For the purpose of the extension process, atypical sliding bearings were mounted on the piers, consisting of special elastomer bearings and load-distributing steel girders provided with stainless sheet coating upon which rested the sliding plates. Horizontal forces were transmitted to the steel frame encased in the concrete of the pier. Lateral guiding devices were also part of this frame. The deflection of the free end of the bridge before reaching a pier was compensated by slightly lifting the superstructure using a run-up flap with a hydraulic attachment – see Fig. 6.

The most demanding stages of construction were faced during the 8th and 11th extension cycle, over a length of 76 and 49.5 m, in the spans 2 and 3 where an assembling support fixture had to be used which rested on a floating support (riverboat) – see Fig. 6. An indispensable requirement that had to be met by the floating support was the ability to adjust its height on an ongoing basis. The movements of the floating support were driven by the bridge structure while sliding out, to which the support was firmly attached. The position of the riverboat was secured by four hawsers anchored on the riverbanks and by one hawser 220 m long anchored upstream in the bottom of the Danube within the axis of the river. Cross-wise the position was additionally secured by a tugboat. All stages of the extension process was subjected to a thorough analysis and were so planned as to avoid any overloading of the steel structure and of the riverboats. In the calculations due account was taken of the extra-high geometry of the structure. The rigidity of the floating support and the effect of the difference in elevation between the circular trajectory of the slide-out process and the horizontal displacement of the riverboat over the water surface. The rectification steps were preprogrammed based on this analysis. The slide-out project involved prescribed positional deviations of the superstructure. The forces at play within the assembling support and any changes in draft of the vessel. These were systematically controlled during the course of the slide-out. The forces within the floating support were determined at important moments of the slide-out directly by taking readings on the hydraulic presses employed. Changes in draft of the vessel were also measured during the entire operation. In case of overstepping the admissible positional deviations or deviations of the forced acting upon the floating support the slide-out process had to be suspended and the elevation of the support elements rectified.

The spans 1 and 6 plus a part of span 5 were assembled while the final position has already been reached i.e., after the extension of the entire structure has been complete.

Fig. 6. Run-up flat, floating support

8. Bridge accessories

In the roadway part of the bridge there are Freyssinet rack type expansion joints seated in reinforced concrete cross-beams. The rails will dilate independently following the abutments. In view of a relatively high gradient (4.16 %) the bearing on the abutments are seated along the longitudinal tilt of the bridge so as to avoid rails being lifted up at the dilation point. Railings on both sides of the sidewalks are made of steel filled with expanded metal. Protection in the case of a rail vehicle crashing against the main supports is by Fracasso 3n 36706 barriers capable of H3 level retention. Underneath the bridge deck there are technical spaces allowing for the transference of a great number of utilities. On the outer side of the main supports there is a revision footbridge. The flooring of the technical cubicles and of the revision footbridge is of steel grating and the walls are provided with expanded metal paneling. The viewing terraces are equipped with a dais on where there are wooden benches, waste baskets, and column luminaires. On the sidewalk side there are boxes with shrub greenery. Lighting of the bridge is by a system of luminaires mounted on the superstructure.